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No effect of age on emotion recognition after accounting for cognitive factors and depression

Jennifer Murphy[1*], Edward Millgate[2], Hayley Geary[2], Caroline Catmur[2], Geoffrey Bird[1,3]

[1]Social, Genetic and Developmental Psychiatry Centre, Institute of Psychiatry, Psychology and Neuroscience, King's College London

[2]Department of Psychology, Institute of Psychiatry, Psychology and Neuroscience, King's College London

[3]Department of Experimental Psychology, University of Oxford

*Corresponding author: Jennifer.Murphy@kcl.ac.uk

+ 44 (0) 207 848 5410

Social, Genetic and Developmental Psychiatry Centre

Institute of Psychiatry, Psychology and Neuroscience - PO80

De Crespigny Park,

Denmark Hill, London,

United Kingdom, SE5 8AF

Abstract

A decline in emotion recognition ability across the lifespan has been well documented. However, whether age predicts emotion recognition difficulties after accounting for potentially confounding factors which covary with age remains unclear. While previous research suggested that age-related decline in emotion recognition ability may be partly a consequence of cognitive (fluid intelligence, processing speed) and affective (e.g., depression) factors, recent theories highlight a potential role for alexithymia (difficulty identifying and describing one's emotions), and interoception (perception of the body's internal state). The present study therefore aimed to examine the recognition of anger and disgust across the adult lifespan in a group of 140 20-90-year olds to see whether an effect of age would remain after controlling for a number of cognitive and affective factors potentially impacted by age. In addition, using an identity recognition control task, the study aimed to determine whether the factors accounting for effects of age on emotion discrimination also contribute towards generalised face processing difficulties. Results revealed that discrimination of disgust and anger across the lifespan was predicted by processing speed and fluid intelligence, and negatively by depression. No effect of age was found after these factors were accounted for. Importantly, these effects were specific to emotion discrimination; only crystallised intelligence accounted for unique variance in identity discrimination. Contrary to expectations, although interoception and alexithymia were correlated with emotion discrimination abilities, these factors did not explain unique variance after accounting for other variables.

Keywords: Ageing, Alexithymia, Emotion Recognition, Interoception, Face Processing

Introduction

A decline in emotion recognition abilities with advancing age has been well-documented. Following early descriptions of deficits (e.g., Calder et al., 2003; Malatesta, Izard, Culver, & Nicolich, 1987), a substantial body of research now suggests that older adults experience difficulties recognising emotional states from facial, bodily and vocal stimuli, as well as integrating emotional signals across multiple domains (e.g., Ruffman, Henry, Livingstone, & Phillips, 2008; Gonçalves et al., 2018). Although it is still debated as to whether difficulties extend across all emotional categories (i.e. all six basic emotions), or are restricted to specific emotion categories (e.g., negative emotions), there is relative consensus that some emotion recognition capabilities decline as a function of normal ageing (although the degree of decline may depend on stimulus features (e.g., ambiguity of stimuli; Montagne, Kessels, De Haan, & Perrett, 2007; Orgeta & Phillips, 2007; Sullivan & Ruffman, 2004) and sample characteristics (e.g., years of education; see Gonçalves et al., 2018 for a recent meta-analysis)). Understanding this decline may be of considerable import given that emotion recognition capabilities are considered to be a central component of nonverbal communication (Ruffman et al., 2008), with difficulties consistently linked to reduced well-being (e.g., Carton, Kessler, & Pape, 1999; Ciarrochi, Chan, & Caputi, 2000; Feldman, Philippot, & Custrini, 1991; Shimokawa et al., 2001). Loneliness and social isolation are particularly prevalent and problematic in later stages of life (see Dickens, Richards, Greaves, & Campbell, 2011), and it is likely that difficulties in social communication may contribute to, or exacerbate, this social isolation in older adults. Understanding emotion recognition ability across the lifespan is therefore an important research goal.

Given the importance of emotion recognition capabilities for well-being across the lifespan (e.g., Carton, Kessler, & Pape, 1999; Phillips, Scott, Henry, Mowat, & Bell, 2010) many recent studies have aimed to identify the factors contributing towards the decline in emotion recognition capabilities in later life. For example, research suggests that a reduction in processing speed may contribute towards the difficulties older adults experience with emotion recognition (West et al., 2012; Suzuki & Akiyama, 2013; Orgeta & Phillips, 2007; Horning, Cornwell, & Davis, 2012; but see Ebner & Johnson, 2009; Sullivan & Ruffman, 2004), whereas higher general intelligence (IQ; sometimes quantified by years of education in previous studies) may represent a protective factor (e.g., Horning et al., 2012; Kessels, Montagne, Hendriks, Perrett, & Haan, 2014; Suzuki, Hoshino, Shigemasu, & Kawamura, 2007; Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; but see Zhao, Zimmer, Shen, Chen, & Fu, 2016; Orgeta & Phillips, 2007). Specifically, the ability to recognise certain emotions has been associated with age-related changes in fluid intelligence (the ability to apply logic to new problems), rather than crystallised intelligence (learned experience and knowledge; Horn & Cattell, 1967) (e.g., Suzuki et al., 2007; Horning, et al., 2012; Suzuki & Akiyama, 2013; but see Sullivan & Ruffman, 2004). Although not all studies examine the predictors of age-related decline in emotion recognition for each emotion separately, some that have suggest that the influence of general cognitive abilities (e.g., processing speed, fluid intelligence) may not extend to all emotions. Notably, there is evidence that certain measures of fluid intelligence do not explain age differences in the recognition of anger or disgust (Suzuki & Akiyama, 2013), though a recent meta-analysis indicated that years of education (which is often associated with IQ) was a moderator for age group differences in disgust and sadness. Findings such as these highlight the need for further information on the factors influencing age-related decline in the recognition of emotions in general, and anger and disgust specifically. In addition to cognitive abilities, affective factors have also been proposed to play a role in emotion recognition capabilities. Specifically, an increase in depressive traits in later life has been linked to more pronounced emotion recognition difficulties (Orgeta, 2014). While many studies have investigated one, or a small number, of the factors contributing to the decline in emotion recognition ability with age, as far as we are aware no previous study has examined whether age predicts emotion recognition difficulties after accounting for a broad range of cognitive and affective traits.

In addition to the factors highlighted above, it has recently been suggested that increased levels of alexithymia, a sub-clinical condition characterised by difficulties identifying and describing one's own emotions (Nemiah, 1977), may contribute towards reduced emotion recognition ability with age (Murphy, Brewer, Catmur, & Bird, 2017). Such a claim is based on evidence that alexithymia is predictive of difficulties recognising the emotional states of others from both facial and vocal stimuli in younger adults (Brewer, Cook, Cardi, Treasure, & Bird, 2015; Cook, Brewer, Shah, & Bird, 2013; Heaton et al., 2012; Bird & Cook, 2013; Grynberg, Chang, Corneille, Maurage, Vermeulen, Berthoz, & Luminet, 2012) and that the incidence of alexithymia increases across the adult lifespan (Henry et al., 2006; Pasini, Delle Chiaie, Seripa, & Ciani, 1992; but see Gunzelmann, Kupfer, & Brähler, 2002). Consistent with this claim, there is some evidence that levels of alexithymia are correlated with the ability to label certain expressions and recall emotional faces in older, but not younger, adults (Grady, Hongwanishkul, Keightley, Lee, & Hasher, 2007; Keightley et al., 2006). However, whether alexithymia is a significant determinant of emotion recognition across the lifespan after controlling for other possible confounds (e.g., depression; Hendryx, Haviland, & Shaw, 1991), remains unclear.

A growing body of evidence suggests that alexithymia is associated with difficulties perceiving the internal state of one's body ('interoception'; Borhani, Làdavas, Fotopoulou, & Haggard, 2017; Brewer, Cook, & Bird, 2016; Gaigg, Cornell, & Bird, 2016; Longarzo et al., 2015; Shah, Hall, Catmur, & Bird, 2016; Murphy, Catmur & Bird, 2018a; Bornemann, & Singer, 2017; Murphy, Brewer, Hobson, Catmur, & Bird, 2018b.; but see Zamariola, Vlemincx, Luminet, & Corneille, 2018; Nicholson et al., 2018). Interoception, often quantified using measures of cardiac perception such as heartbeat tracking and discrimination procedures (Schandry, 1981; Whitehead, Drescher, Heiman, & Blackwell, 1977), has been consistently linked to both general emotional processing (Füstös, Gramann, Herbert, & Pollatos, 2013; Schandry, 1981; Terasawa, Fukushima, & Umeda, 2013; Wiens, Mezzacappa, & Katkin, 2000) and emotion recognition abilities specifically (Terasawa, Moriguchi, Tochizawa, & Umeda, 2014). Crucially, however, like alexithymia, changes in interoceptive accuracy (e.g., performance on objective tests of interoception) and awareness (e.g., self-reported awareness of interoceptive signals; see Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015; Murphy et al., 2018a) are reported across the lifespan, with increasing age associated with worse perception of bodily signals (Khalsa, Rudrauf, & Tranel, 2009; Murphy, Geary, Millgate, Catmur, & Bird, 2017). Given these links between interoception, alexithymia, emotional processing and ageing, it is possible that emotion recognition ability across the lifespan is predicted by levels of both alexithymia and interoceptive accuracy.

In addition to identifying the predictors of emotion recognition across the lifespan, and whether these impact upon the relationship between age and emotion recognition, it is important to determine the specificity of their effect; it is likely that cognitive and emotional changes observed across the lifespan could impact upon a number of social abilities. For example, a body of evidence indicates that older adults also exhibit generalised difficulties with faces, including identity recognition (e.g., Germine, Duchaine, & Nakayama, 2011), and adopt a more piecemeal (featural) face processing strategy (e.g., Boutet, Taler, & Collin, 2015). Whilst some studies investigating the link between age and emotion recognition abilities have utilised control conditions to determine the specificity of deficits (e.g., gender judgements, age ratings, face perception or object recognition tasks; e.g., Ebner & Johnson, 2009; Yang, Penton, Köybaşı, & Banissy, 2017), to our knowledge no study has examined whether the cognitive or affective factors that predict emotion recognition ability across the lifespan are specific to emotion recognition, or also extend to other aspects of face processing.

The present study therefore aimed not only to identify specific cognitive and affective factors that predict discrimination of anger and disgust (hereafter for brevity 'emotion recognition') across the lifespan and examine whether any effect of age remains after accounting for these factors, but also to determine their relative contribution. Specifically, this study examined whether alexithymia and poor interoception predict emotion recognition abilities across the lifespan in addition to previously identified factors (processing speed, intelligence, depression) while controlling for factors associated with the potential predictors. For example, anxiety commonly co-occurs with alexithymia and depression (e.g., Hendryx, Haviland, & Shaw, 1991; Kendall, & Watson, 1989), and gender differences have been reported for emotion recognition and rates of depression (e.g., Williams et al., 2009; Piccinelli & Wilkinson, 2000). As such, these factors were included in analyses to ensure the potentially confounding effect of these factors was controlled for. Moreover, to establish the specificity of these relationships, participants also completed an identity recognition control task to investigate whether any observed effects were specific to emotion recognition, or also extend to the recognition of identity.

Method

Participants

140 participants took part in this study in exchange for a small honorarium. With respect to sample size, recruitment continued until there was a minimum of five participants in each 5-year age bracket from 20-90 years. Participants were selected on the basis that they had no known psychiatric or neurological conditions and normal or corrected-to-normal visual acuity. To screen for cognitive impairment, all participants were administered the Mini

Mental State Examination test (MMSE; Folstein, Folstein, & McHugh, 1975), with scores below 23 indicative of cognitive impairment (Tombaugh & McIntyre, 1992). Four participants were excluded (one scored below threshold on the MMSE; two disclosed existing psychiatric/neurological conditions post-testing; one was excluded due to equipment failure). For two participants, data were missing for the emotion-identity task (one participant withdrew participation and one participant's data were lost due to a computer error) and these cases were removed. This resulted in 134 valid cases (M_{age} = 54.95, SD_{age} = 19.54, Range 20-90 years, 49 males). One participant's depression score was missing, and this data point was imputed using multiple imputation in SPSS. Ethical approval was granted by the local ethics subcommittee. In line with the declaration of Helsinki, all participants gave informed consent and were fully debriefed upon task completion. To minimise the effects of elevated heart rate on accuracy on the cardiac interoception task (Knapp-Kline & Kline, 2005), all participants were asked to refrain from caffeine for approximately six hours prior to testing.

For some participants it was not possible to fit the planned psychophysical functions to analyse their data for either the emotion (N = 18) or identity (N=2) tasks (responses did not follow a sigmoidal pattern suggestive of no sensitivity to stimulus strength), and 3 further participants were statistical outliers (>3x the interquartile range; 2 for the identity task and 1 for the emotion task). Importantly, these excluded individuals differed from the remaining sample on several factors; excluded individuals were significantly older, had poorer processing speed, lower fluid intelligence, higher alexithymia and higher depressive traits; all $p<.05$). So as not to underestimate the influence of these factors, results are reported using a different analysis strategy (see scoring and data analysis) for the total sample of 134 participants. However, for completeness the results from the reduced sample (113 participants; Mage = 52.97, SDage = 19.42, Range 20-90 years, 43 males) using the planned analyses are reported in the supplementary materials [S1-S6]. Even after exclusions, in both analysis samples, a minimum of five participants were present in each 5-year age bracket.

Emotion-Identity recognition task

The Emotion-Identity recognition task was taken from Cook et al., (2013). This paradigm was selected on the basis that previous evidence suggests that emotion recognition tests are most sensitive to age-related changes when they involve ambiguous stimuli, such as the morphed faces used in this paradigm (Montagne, Kessels, De Haan, & Perrett, 2007; Orgeta & Phillips, 2007; Sullivan & Ruffman, 2004). Although this task presents only two emotions, this was preferred to an omnibus test of emotion recognition in order to gain a precise estimate of emotion recognition ability for these emotions. Moreover, due to evidence that cognitive abilities may not be predictive of age-related decline for these emotions specifically (e.g., Suzuki & Akiyama, 2013), disgust and anger were selected on the basis that the additional factors examined here may predict age-related decline in their recognition. Moreover, identity recognition was selected as a control condition given evidence that emotion and identity recognition may rely on partly dissociable mechanisms (Biotti & Cook, 2016; Bruce & Young, 1986; Calder & Young, 2005; Duchaine, Parker, & Nakayama, 2003; Haxby, Hoffman, & Gobbini, 2000). The task has the advantage that the identity and emotion recognition judgements are performed on the same stimuli (and therefore the stimulus sets for both judgments are matched on all low-level properties). This is important as there is some evidence that age effects on low-level visual perception may contribute to age-related face perception differences (e.g., Boutet et al., 2015). Finally, when encoding the stimuli, participants are unaware whether they will be asked to report the emotion or identity of the face and therefore must process both stimulus attributes at the same time, as in everyday life.

In the Emotion-Identity recognition task, trials begin with a 1500ms fixation cross followed by the face of one of two identities (Harold or Felix; see Figure 1) depicting one of two expressions (Disgust or Anger) for 800ms. Following stimulus offset, participants are prompted to make a judgement regarding either the identity (“Harold or Felix?”) or the expression (“Disgust or Anger?”) of the face shown, with the response immediately triggering the start of the next trial. As in the original task, faces were morphed along both expression and identity dimensions; a continuum derived from morphing Harold expressing anger with Felix expressing disgust, and the complementary continuum derived from morphing Harold expressing disgust with Felix expressing anger in 10% steps from 20% intensity to 80% intensity. These continua together comprised the Disgust-Anger cross-morph set. Original greyscale images were taken from Ekman and Friesen (1976) (identities M4, M6, F4 and F5) and were morphed using Morpheus Photo Morpher version 3.11 (Morpheus Software LLC, Indianapolis, USA). For both the identity and expression recognition tasks, participants completed 20 trials at each of the seven levels of intensity resulting in 140 trials per task. Sessions comprised 10 blocks of 28 experimental trials lasting approximately 25 minutes. The experimental programme was programmed in Matlab with psychtoolbox extensions (Brainard, 1997; Pelli, 1997). This relatively short exposure duration (800ms) was selected so that data could be compared to previous studies (e.g., West et al., 2012). The use of short presentation times for static faces may also have better ecological validity as it likely requires a speed of processing similar to that required during real-world social interaction (Ruffman, 2011).

[Figure 1]

Cognitive ability

Processing speed

Processing speed was quantified using the coding and symbol search tasks from the Wechsler Adult Intelligence Scale, Fourth Edition (WAIS-IV; Wechsler, 2008). The order of completion was counterbalanced.

Intelligence (FSIQ-2)

Intelligence was measured using the Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II; Wechsler, 2011), with two subscales employed (matrix reasoning and vocabulary). Across participants, the order of completion (matrix first vs vocabulary first) was counterbalanced. Age-normed WASI-II scores served as a measure of intelligence (FSIQ-2) and, in a separate analytic model, scores for each subscale (matrix reasoning and vocabulary) served as measures of fluid and crystallised intelligence, respectively.

Interoception task

The heartbeat tracking task (Schandry, 1981) was used to quantify interoceptive accuracy with timing ability employed as a control task (Ainley, Brass, & Tsakiris, 2014; Murphy, Geary, et al., 2017; Shah et al., 2016). Objective heartbeat was measured using a pulse oximeter attached to the participant's index finger. Each participant completed both the heartbeat tracking task and the timing task over four durations. Two sets of durations were used (either 25, 35, 45, 100 seconds or 28, 38, 48, 103 seconds) and duration set was counterbalanced across participants such that half of the participants completed the longer durations for the timing task and half completed the longer intervals for the heartbeat task. Additionally, task order was counterbalanced, and the order of individual durations was counterbalanced according to a Latin-square across participants. No significant differences in interoceptive accuracy were observed as a function of task order, $t(132) = -1.644$, $p > .05$, $d =$

.28, CI for *d* [-.06, .62]. Likewise, no order effect was observed for performance on the timing task, $t(122.08) = 1.398$, $p>.05$, $d = .24$, CI for *d* [-.01, .58].

During the task participants were seated with both feet flat on the floor and both hands on the table. Participants were instructed that they would be asked to silently count their heartbeats over a period of time without physically measuring their heartbeat. With their eyes closed they were asked to count their heartbeats from when the experimenter said “start” until they heard a beep, at which point they should indicate the number they had counted. They were explicitly told to only count heartbeats they felt and not to count seconds or guess. Participants were also told if they did not feel anything they should give zero as their answer. Participants were then given two minutes to practice prior to the first heart rate trial, no feedback was provided. The timing task was identical to the heartbeat task except participants were asked to count seconds rather than their heart beats.

A number of additional control measures were also employed for the HCT. These included body-mass index (BMI), resting heart rate (HR), heart rate variability (HRV), systolic blood pressure and beliefs regarding the average resting heartrate (see Murphy et al., 2017; Murphy et al., 2018a, and supplementary materials [S7] for details).

Questionnaire measures

Three questionnaires were employed, the Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994), State and Trait Anxiety Inventory (STAI; Spielberger, 1983) and the Beck Depression Scale (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961), to measure alexithymia, state and trait anxiety, and depression, respectively. These measures have been shown to be valid and to have good reliability in older age groups (Henry et al., 2006; Kvaal, Ulstein, Nordhus, & Engedal, 2005; Gallagher, Nies, & Thompson, 1982).

Task counterbalancing

Task order was varied across participants. Half of participants completed the emotion-identity recognition task first and half completed the other measures (fluid and crystallised intelligence, processing speed, interoception, MMSE) first. Moreover, the order of completion for the four other measures (fluid and crystallised intelligence, processing speed, interoception, MMSE) was Latin-square counterbalanced. As previously described, within each task (e.g., processing speed) the order of dual tasks (e.g., symbol search vs. coding) was counterbalanced.

Analysis strategy

Zero-order correlations revealed the associations between age and emotion/identity recognition as well as the relationship between age and the potential predictors of emotion recognition ability. The size of the correlations between age and emotion recognition, and age and identity recognition, scores were compared using Steiger's Z-test (Steiger, 1980) using the quantpsy web implementation (Lee & Preacher, 2013). Correlations were then used to examine the association between the potential predictors and performance on the emotion/identity recognition tasks.

Given recent arguments against the use of mediation analyses with cross sectional data (Cole & Maxwell, 2003; Maxwell, Cole, Mitchell, 2007) regression analyses were utilised to examine the unique variance explained by each potential predictor, and to determine whether an effect of age would remain after accounting for these predictors. Entry method regressions were conducted in which age (years), gender (0 = male, 1= female), processing speed, alexithymia, depression, state anxiety, trait anxiety, interoceptive accuracy (scores controlling for confounds are reported but it is important to note that the use of raw scores for the heartbeat counting task did not alter the pattern of results obtained for any of the regression analyses described below), and FSIQ-2 (model one) or fluid and crystallised intelligence (model two) were entered as predictors of both identity and emotion recognition performance.

As the data did not meet the assumptions of a normal distribution (moderate skew was present), robust regression was utilised for all regression analyses. Robust regression was favoured over the ordinary least squares method as it is less sensitive to departures from normality (Field & Wilcox, 2017). Robust regressions were conducted in MATLAB 2014a (The MathWorks, Natick, 2014) and for all analyses the default weight function (bisquare) with the default tuning constant (4.685) was utilised. For all models, R^2 was manually calculated by correlating the observed scores with the expected scores. The R values were then squared. Expected scores were calculated using the constant and beta values from the robust regression using the equation ($y = bX_1 + bX_2 + bX_3 \ldots .. + c$).

Scoring and data analysis

Interoception task

Interoceptive accuracy on the heartbeat tracking task was estimated on a scale from 0 – 400: Σ(1 – (|Actual number of heartbeats – participant's estimate|/Actual number of heartbeats)) x 100. Higher scores indicate better performance (Murphy, Geary, et al., 2017; Shah et al., 2016). Timing scores were estimated similarly, Σ(1 – (|Actual number of seconds – participant's estimate|/Actual number of seconds)) x 100. Again, high scores indicate better performance. An interoception score controlling for time perception ability, systolic blood pressure, HRV, resting HR and BMI was then created by regressing out all variance on the interoception measure explained by these factors across participants. The residuals from this regression comprised the 'interoception controlling for confounds' score.

Emotion-Identity task

As noted, for a number of participants it was not possible to fit functions as originally intended (responses did not follow a sigmoidal pattern; see Participants). So as not to exclude a sizeable number of participants who systematically differed from the remaining sample on a number of key variables (see Participants), alternative analyses were conducted in order to retain these participants (N=134). To derive emotion and identity scores for these participants hit-false alarm (i.e., number correct when signal present – number incorrect when signal absent) rates were calculated for both the identity and emotion recognition scores separately (excluding performance on trials where stimuli were 50-50 intensity; note that a hit refers to selecting the response corresponding to the emotion presented at least at 60% intensity). Hit-False alarm rates were favoured over d'prime as they do not require the assumption of an underlying normal distribution and are therefore more appropriate for combining performance across a range of stimulus intensities (e.g., morph continua; e.g., Stanislaw & Todorov, 1999). As such, high scores on both the emotion and identity task indicate better performance.

Processing speed

For the coding and symbol search tasks average accuracy scores were calculated. Whilst these scores are ordinarily aged-normed, so as not to remove meaningful effects of age on processing speed scores, the raw scores were utilised. To create an average score across both tasks, a percentage accuracy score was calculated for each task. Percentage accuracy scores across the two tasks were then averaged and this average accuracy score served as a measure of processing speed with high scores indicative of increased processing speed.

Intelligence

Previous research examining the contribution of intelligence to age-related changes in emotion recognition abilities generally employed one of the following scoring methods; 1) using years of education to approximate intelligence (e.g., Zhao, Zimmer, Shen, Chen, & Fu, 2016; Orgeta & Phillips, 2007) given that age-normed intelligence scores and years of education are highly correlated (e.g., Matarazzo, & Herman, 1984; Murayama et al., 2013), or 2) calculating fluid and crystallised intelligence scores for each subtest without age-norming (e.g., Horning et al., 2012; Suzuki & Akiyama, 2013). Because of discrepancies in the literature regarding the contribution of intelligence measures to emotion recognition abilities, which may depend upon the method employed (e.g., Horning et al., 2012; Kessels, Montagne, Hendriks, Perrett, & Haan, 2014; Suzuki, Hoshino, Shigemasu, & Kawamura, 2007; Sullivan & Ruffman, 2004; Zhao, Zimmer, Shen, Chen, & Fu, 2016; Orgeta & Phillips, 2007), both scores were calculated in this sample; age-normed FSIQ-2 from the verbal and matrix subscales of the WASI, and percentage accuracy scores (Horning et al., 2012) for both the matrix (fluid intelligence) and verbal (crystallised intelligence) subscales that were not age-normed.

Results

Descriptive statistics

Descriptive statistics for all key variables are summarised in Table 1 (additional descriptive statistics for HCT control variables and subsample analyses can be found in supplementary materials; [S2; S9). For questionnaire measures, in the total sample eight participants met cut off for alexithymia (scores >=61), twenty for mild mood disturbance

(BDI scores between 11-16) and five for borderline/moderate clinical depression (BDI scores between 17 – 30).

[Table 1]

Correlational analyses

Correlations between all key variables are summarised in Table 2 (for correlations in the subsample see supplementary materials [S3]; for correlations between HCT control variables see supplementary materials [S10]). As predicted, increasing age was associated with increasing error on both the emotion recognition task (*r*(132 = -.466, *p*<.001) and the identity recognition task (*r*(132) = -.333, *p*<.001). When formally compared, the sizes of the correlations between ageing and emotion recognition, and ageing and identity recognition, were not significantly different (*z* = 1.74, *p* = .08). Average performance was better for the identity task than the emotion recognition task (*t*(133) = -8.09, *p*<.001) and performance on the two recognition tasks was moderately correlated (*r*(132) = .519, *p*<.001. Analyses were conducted in order to test for quadratic relationships between age and emotion, and age and identity, recognition ability in the full sample, finding only a linear relationship (see supplementary materials [S11]).

As predicted, in the total sample increasing age was significantly negatively associated with processing speed, fluid intelligence and interoceptive accuracy, and positively associated with alexithymia (all *p*<.05; Table 2). Increasing rates of alexithymia as a function of age were observed for all three subscales of the TAS-20; Difficulties Identifying Feelings (*r*(132) = .233, *p*=.007), Difficulties Describing Feelings (DDF; *r*(132) = .175, *p*=.043), and Externally Oriented Thinking (*r*(132) = .234, *p*=.006). In contrast, age was not associated with normed FSIQ-2, crystallised intelligence, state or trait anxiety or interoceptive accuracy after controlling for confounds (all $p>.05$).

Whilst not reported in Table 2, it is important to note that gender differences were not observed. Of all the variables, only a trend was observed whereby women had worse interoceptive accuracy after controlling for possible confounds ($t(132) = 1.917$, $p=.057$). In terms of the relationship between the dependent variables (emotion and identity recognition) and the potential predictors of performance on these tasks, in the total sample poor performance on the emotion recognition task was associated with increased total alexithymia, depression and state anxiety scores (all $p<.05$; Table 2), whereas increasingly accurate performance was associated with increases in processing speed, interoceptive accuracy, and all intelligence measures (all $p<.05$). Only trait anxiety, gender and interoceptive accuracy after controlling for confounds were unrelated to emotion recognition abilities (all $p>.05$). In contrast, only processing speed and fluid intelligence were correlated with performance on the identity recognition task, whereby higher processing speed and fluid intelligence correlated with better performance.

[Table 2]

Regression analyses

Model 1: intelligence measures as age-normed FSIQ-2

In Model 1, we included a measure of intelligence that was age-normed and combined measures of fluid and crystallised intelligence into a measure of FSIQ-2. This was conducted to provide a conceptual replication of previous literature that has found an effect of intelligence or years of education on emotion recognition performance (e.g., Horning et al., 2012; Kessels, Montagne, Hendriks, Perrett, & Haan, 2014; Suzuki, Hoshino, Shigemasu, &

Kawamura, 2007; Keightley, Winocur, Burianova, Hongwanishkul, & Grady, 2006; but see Zhao, Zimmer, Shen, Chen, & Fu, 2016; Orgeta & Phillips, 2007).

Emotion task

To examine the unique variance explained by each potential predictor, and whether age would account for significant variance after accounting for these potential predictors, an entry method robust regression was conducted predicting emotion recognition performance from gender (0 = female, 1 = male), age (years), FSIQ-2 (age-normed), processing speed, interoceptive accuracy (controlling for all confounds) alexithymia, depression, state and trait anxiety. Standardized beta values are reported for all regression analyses. Results from the model suggested that age-normed FSIQ-2 (b = .193, t = 2.747, p=.007) and processing speed (b= .317, t = 3.393, p=.001) uniquely predicted greater emotion recognition ability, whereas depression scores predicted worse emotion recognition ability (b = -.275, t = -2.937, p=.004). No significant effect of any other factor, including age, was observed (all p>.21). R^2 for the full model was 43.15%.

Identity task

The same regression analyses were conducted for identity recognition performance. However, none of the examined factors significantly predicted unique variance in identity recognition performance (all p>.17). R^2 for the full model was 19.64%.

Model 2: Fluid and crystallised measures of intelligence

In the preceding analyses a measure of FSIQ-2 was included that was age-normed. To examine whether effects would be observed when 1) scores were not age-normed and 2) when measures of fluid and crystalized intelligence were examined separately, the regression analyses were repeated including percentage scores for the fluid and crystallised intelligence subscales of the WASI in the place of FSIQ-2. This analysis was conducted on the basis that previous literature suggests that fluid, but not crystallised intelligence may be predictive of age-related changes in emotion recognition (e.g., Suzuki et al., 2007; Horning, et al., 2012; Suzuki & Akiyama, 2013; but see Sullivan & Ruffman, 2004).

Emotion task

As in the first regression analysis, an entry method robust regression was conducted predicting emotion recognition performance from gender (0 = female, 1 = male), fluid intelligence, crystallised intelligence, processing speed, interoceptive accuracy (controlling for confounds), alexithymia, depression, state and trait anxiety and age. Results revealed that increasing emotion recognition performance was positively predicted by processing speed (b = .273, t = -2.880, p=.005) and fluid intelligence (b = .233, t = 2.680, p=.008), whereas increasing depressive traits predicted worse performance (b = -.241, t = -2.603, p=.010). All other predictors were non-significant (all p>.11). R^2 for the full model was 46.20%.

Identity task

The same regression analyses were conducted for identity recognition performance. Results revealed that only crystallised intelligence (b = .169, t = 2.188, p=.031) accounted for unique variance in identity recognition performance, with a trend for age to predict poor performance also observed (b = -.186, t = -1.766, p=.080). All other predictors were not significant (all p>.24). R^2 for the full model was 16.88%.

Discussion

This study aimed to examine the factors that predict emotion recognition across the lifespan and to uncover whether any effect of age would remain after accounting for these factors. As expected, with advancing age, performance on emotion and identity recognition tasks decreased. Moreover, as predicted, age was associated with reduced processing speed, reduced fluid intelligence and poorer interoception (before accounting for potential confounds), as well as increased rates of alexithymia and depressive traits. Examination of the specific contribution of these factors to emotion and identity recognition abilities across the lifespan indicated that processing speed, fluid intelligence and depression accounted for unique variance in emotion recognition performance across the lifespan. Importantly, after accounting for these factors no remaining effect of age on emotion recognition scores was observed. In contrast, processing speed, fluid intelligence and depression did not account for unique variance in identity recognition ability across the lifespan. Indeed, of all the examined factors only increasing crystallised intelligence made a unique contribution to improved identity recognition performance, with a trend observed for age to be associated with poor performance after accounting for all other factors. As such, it appears that different factors may contribute towards emotion and identity recognition ability across the lifespan. Thus, these data confirm previously-reported evidence that processing speed, fluid intelligence and depression may explain age-related decline in emotion recognition ability (e.g. Orgeta, 2014; West et al., 2012; Suzuki & Akiyama, 2013; Orgeta & Phillips, 2007; Horning et al., 2012; but see Ebner & Johnson, 2009; Sullivan & Ruffman, 2004), and go further to suggest that the influence of these factors is specific, and independent of other previously identified, and newly examined, factors.

Consistent with previous reports, this study found that cognitive factors contributed towards emotion recognition ability. First, the finding that reduced processing speed contributes towards emotion recognition ability across the lifespan is consistent with previous evidence demonstrating that processing speed and emotion recognition ability share common variance (West et al., 2012). However, which sub-processes within emotion recognition are impacted by reduced processing speed remains unclear. One suggestion is that poor processing speed contributes towards difficulties with the speeded component of emotion recognition tasks (West et al., 2012). In our study, processing speed did not significantly predict identity recognition after accounting for all other factors (despite using a task with the same temporal structure), but it is possible that processing speed impacts speeded tasks of emotion recognition specifically. Therefore, whether a similar effect of processing speed on emotion recognition abilities across the lifespan would be observed in tasks without temporal constraints (i.e. where older adults are allowed to inspect the image for lengthy durations) is a question for future research. It is possible, therefore, that temporal factors may explain the somewhat variable results regarding the contribution of processing speed to emotion recognition in later life (e.g., Ebner & Johnson, 2009; Sullivan & Ruffman, 2004; West et al., 2012; Zhao et al., 2016).

Second, whilst age-normed FSIQ-2 scores were unsurprisingly uncorrelated with age, age-normed FSIQ-2 did significantly predict enhanced emotion recognition abilities in the first model. Such findings are in line with previous evidence indicating a relationship between years of education, which is highly correlated with intelligence (e.g., Matarazzo, & Herman, 1984; Murayama et al., 2013), and emotion recognition ability (e.g., Keightley, et al., 2006; Kessels et al.,2014). Importantly, these data also highlight the consequences of age-related changes in fluid intelligence (Horn, & Cattell, 1967). Whilst some previous evidence suggests that fluid intelligence does not contribute towards the recognition of disgust and anger (e.g., Suzuki & Akiyama, 2013), in this sample, fluid intelligence, but not crystallised intelligence, was found to be a significant predictor of the ability to recognise disgust and anger (see also Suzuki et al., 2007; Horning, et al., 2012; but see Suzuki & Akiyama, 2013; Sullivan & Ruffman, 2004 for conflicting findings). These data are in line with the proposal that preserved fluid intelligence may be a protective factor against age-related changes in emotion recognition abilities (Horning et al., 2012), and suggest that discrepancies in the literature regarding the contribution of intelligence to age-related changes in emotion recognition abilities (e.g., Zhao et al., 2016; Orgeta & Phillips, 2007) may be due to the measure employed (e.g., years of education vs. fluid intelligence measures).

In addition to cognitive factors, emotion recognition difficulties were also predicted by increased depressive traits. Such findings are consistent with previous evidence that depressive symptoms contribute towards emotion recognition impairments in later life (Orgeta, 2014), and a body of literature documenting emotion recognition difficulties in clinical depression (see Bourke, Douglas, & Porter, 2010). What remains unclear, however, is the mechanism by which depressive traits confer difficulties in emotion recognition across the lifespan; it is equally possible that poor emotion recognition ability results in increased depressive traits (as previous studies have shown poor social skills are linked to depression; for a review see Segrin, 2000), or that increased depressive traits result in poor emotion recognition. Longitudinal studies are required to fully elucidate the relationship between these factors.

Whilst a comparable age-related decline in identity recognition was observed, the factors predicting emotion recognition performance were specific; none of the factors that predicted emotion recognition performance predicted identity recognition performance. Indeed, these data are consistent with evidence that recognition of the transient and stable characteristics of faces partly dissociate (Biotti & Cook, 2016; Bruce & Young, 1986; Calder & Young, 2005; Duchaine et al., 2003; Haxby et al., 2000) and that identity recognition is not predicted by affective traits (e.g., Hills, Marquardt, Young, & Goodenough, 2017). Overall therefore, results suggest that processing speed, depression and notably fluid intelligence make a unique contribution towards emotion recognition across the lifespan, which is not the result of a generalised difficulty with face processing. However, unlike previous findings suggesting no relationship between general cognitive abilities and identity recognition (e.g., Wilmer, Germine, & Nakayama, 2014), in this sample crystallised intelligence did predict identity recognition performance. Whilst it is only possible to speculate as to the reason for this discrepancy, it is possible that the measure of face recognition utilised (particularly the memory demands associated with the task), the intelligence measure employed (e.g., measures of only fluid intelligence or combined measures of fluid and crystallised intelligence), the age-range sampled, and the additional factors controlled for, may all play a role in producing disparate results across studies. Importantly, however, unlike emotion recognition, it is notable that a trend was still observed for age to predict decline in identity recognition. Therefore, the factors that significantly contribute towards difficulties with facial identity recognition ability as a function of advancing age remain undetermined, though certain mechanisms such as reduced holistic processing (increased featural processing) or atypical face scanning patterns have been proposed (e.g., Boutet et al., 2015; Firestone, Turk-Browne, & Ryan, 2007).

Whilst effects of processing speed, fluid intelligence and depression on emotion recognition abilities were observed, contrary to predictions no unique effect of interoceptive accuracy or alexithymia was found. Although it is possible that this finding may reflect the true state of affairs, it is worthy of further investigation due to the fact that the current sample had a limited distribution of high alexithymia scores, with only 2.9% of the sample scoring above the threshold indicating the presence of alexithymia, and even those scoring above cut-off did not have especially extreme scores. Therefore, it is possible that the limited distribution of alexithymia scores may have contributed towards reduce power in detecting a unique effect of alexithymia on the relationship between age and emotion recognition, as well as a relationship between alexithymia and interoceptive accuracy[1] (e.g., de Haas, 2018). As well as a limited distribution of scores, it is also possible that the use of the heartbeat

[1] Note that the data pertaining to the relationship between interoceptive and alexithymia has been previously reported as part of a wider investigation reported in Murphy et al., 2018 (see Data Disclosure)

counting task as a measure of interoceptive accuracy may have contributed towards the lack of a unique effect of interoceptive accuracy on emotion recognition. In comparison to studies utilising other measures of cardiac interoception (e.g., Khalsa et al., 2009) the relationship between age and interoceptive accuracy in this sample was comparably small (as reported in Murphy, Geary, et al., 2017). In the context of certain concerns about this measure (e.g., Murphy et al., 2018b) it would therefore be beneficial for future research to assess whether a unique effect of interoception on emotion recognition may be observed using alternative measures of interoceptive accuracy. Nevertheless, although no unique effect of alexithymia and interoception was observed, as expected, interoceptive accuracy and alexithymia decreased and increased with age, respectively (as previously reported in Murphy, Geary, et al., 2017; in line with findings reported by Henry et al., 2006; Khalsa et al., 2009; Pasini et al., 1992; but see Gunzelmann et al., 2002), and both raw heartbeat counting scores (a measure of interoceptive accuracy which has been previously linked to emotion recognition ability) and alexithymia were significantly correlated with emotion recognition abilities (with greater interoceptive accuracy predicting better performance and high alexithymia predictive of worse performance; Brewer et al., 2015; Cook et al., 2013; Grady et al., 2007; Heaton et al., 2012; Keightley et al., 2006; Terasawa et al., 2014).

Of theoretical interest is the possibility that the lack of a significant predictive effect of alexithymia and interoceptive accuracy on emotion recognition distinct from the effect of the other variables in the model reflects the fact that older samples are comprised both of individuals who have had elevated rates of alexithymia across their lives (e.g., trait alexithymia), and of individuals whose alexithymic traits have increased across the lifespan. Although speculative, it is possible that individuals who develop alexithymia later in life do not exhibit the emotion recognition deficits observed in individuals who have trait alexithymia. Likewise, given links between alexithymia and interoception (Borhani et al., 2017; Brewer et al., 2016; Gaigg et al., 2016; Longarzo et al., 2015; Shah et al., 2016; Murphy et al., 2018; Bornemann, & Singer, 2017; but see Zamariola, Vlemincx, Luminet, & Corneille, 2018), a similar explanation may account for the absence of a predictive effect of interoceptive accuracy on emotion recognition abilities over and above the other variables in the model; samples may be comprised of individuals whose interoceptive accuracy has always been impaired (e.g., trait interoceptive impairment) and individuals for whom interoceptive accuracy has decreased as a function of normal ageing. As such, it is crucial that future research takes a longitudinal, developmental focus, and assesses the predictive value of these traits for social-emotional abilities across the lifespan.

Finally, it is important to acknowledge the limitations of this study. First, the study suffered from inherent difficulties quantifying emotion and identity recognition performance across a broad range of abilities. Indeed, for many participants it was not possible to utilise the planned analysis, and the predictors of emotion and identity recognition performance differed across the total sample and the subsample (reported in the supplementary materials). These differences are likely due to reduced power in the subsample, due to the reduction in sample size and the fact that individuals for whom it was not possible to use the planned scoring strategy were more extreme on a number of factors found to be predictors of emotion recognition performance when the whole sample was analysed (e.g., depression and fluid intelligence). However, given this limitation it is important that these results are treated as preliminary. Future research will benefit, therefore, from the development of measures of both emotion and identity recognition ability that are sensitive enough to capture variations at both the high and low ability levels. Second, not all previously highlighted factors were measured; for example, it has been proposed that certain big-5 personality traits may contribute towards differences in emotion recognition abilities (e.g. Matsumoto, 2006). However, as research suggests that elements of personality are not mediators of the relationship between age and emotion recognition abilities (Mill, Allik, Realo, & Valk, 2009) it is unlikely that this would have changed the pattern of results. Third, a body of research indicates an own-age bias in face recognition abilities whereby participants are better at processing faces that are of a similar age to themselves (Rhodes & Anastasi, 2012). Unfortunately, the age of the actors in the stimuli used were not available and therefore we are unable to rule out a contribution of an own-age bias to the results. However, as previous research suggests an own-age bias is not observed for tasks of emotion recognition or memory for emotional faces (Ebner, Johnson, & Fischer, 2012; Ebner & Johnson, 2009), it is unlikely that this would have influenced the observed pattern of results for the emotion recognition task. Fourth, only two negative emotions were examined in this study. Given ambiguity regarding whether the emotion recognition deficits observed in later life are limited to certain emotions, or extend to a number of emotion categories (e.g., Ruffman et al., 2008; though see Gonçalves et al., 2018), it is not possible to conclude that the same pattern of results would be observed for all emotions. Fifth, it is also important to acknowledge that static photographs were used in this study, limiting generalisability of the results (Grainger, Henry, Phillips, Vanman, & Allen, 2015; Krendl & Ambady, 2010). As noted by Kensinger and Gutchess (2017), it is important that future studies assess the factors that contribute towards age-related changes in emotion recognition abilities across naturalistic stimuli involving integration of multiple signals (e.g., the body, face, voice). Such studies may be particularly important given some evidence that age differences are less pronounced with naturalistic stimuli (e.g., Grainger et al., 2015; Krendl & Ambady, 2010), and that the factors accounting for age-related changes may differ for static vs. dynamic emotional stimuli (Krendl & Ambady, 2010). Sixth, it must also be acknowledged that this study employed the heartbeat counting task as a measure of interoception. Given recent concerns over the validity of this measure (see Murphy et al., 2018b for a discussion) it remains a possibility that differential results would be obtained using other measures of interoception. Indeed, heartbeat counting was unrelated to age and emotion recognition after accounting for multiple confounds. As such, it is important that further research assess the relationship between these factors and other measures of interoceptive ability. Seventh, it is important to note that previous evidence suggests that emotion and identity recognition ability may follow an inverted U-shaped curve across the lifespan (Horning et al., 2012; Williams et al., 2009; Germine, Duchaine, & Nakayama, 2011). Whilst, we found no evidence of a quadratic relationship in these data (see supplementary materials [S11]), it may be that the comparatively small sample size employed here, that did not include children and adolescents, contributes to this discrepancy. Finally, it must be noted that as the design was cross-sectional we cannot rule out the possibility that the pattern of results obtained reflect a cohort effect rather than a true effect of ageing.

In conclusion, the results from this study suggest that the ability to recognise emotion, but not identity, across the lifespan is predicted by processing speed, fluid intelligence and depressive traits, and that after controlling for these factors no effect of age remains. Contrary to predictions, no unique effects of interoception or alexithymia were observed after accounting for other factors. These findings contribute to our understanding of the mechanisms by which impairment in emotion recognition occurs across the adult lifespan. They may, in the future, allow interventions to be developed which improve emotion recognition in older adults, and therefore alleviate the social isolation and loneliness which is more frequently experienced at this stage of life.

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Data disclosure

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Table 1. Descriptive statistics

Measure	Mean	Standard Deviation
Age	54.95	19.54
Emotion (Hits-FA)	40.41	16.49
Identity (Hits-FA)	50.28	9.48
Age normed-FSIQ-2	110.82	15.60
Processing Speed	50.54	14.55
Interoception	184.60	132.65
Alexithymia	42.28	10.57
Depression	6.18	5.17
State Anxiety	29.51	7.68
Trait Anxiety	35.37	8.69
Fluid IQ	62.34	17.14
Crystallised IQ	73.36	12.76

Table 2. Correlations in the total sample (N=134)

Measure	1	2	3	4	5	6	7	8	9	10	11	12
1. Age	1											
2. Emotion (Hits-FA)	-.466**	1										
3. Identity (Hits-FA)	-.333**	.519**	1									
4. Age normed-FSIQ-2	.023	.323**	.164	1								
5. PS	-.685**	.544**	.358**	.173*	1							
6. Interoception	-.203*	.182*	.067	.217*	.183*	1						
7. Interoception[a]	-.096	.059	.008	.106	.051	.935**	1					
8. Alexithymia	.255**	-.213*	.031	-.036	-.164	-.088	-.049	1				
9. Depression	.166	-.312**	-.096	-.080	-.104	-.059	.034	.441**	1			
10. State Anxiety	.036	-.171*	-.143	-.087	-.059	-.053	.021	.310**	.504**	1		
11. Trait Anxiety	-.073	-.081	-.050	.068	.013	-.042	-.025	.373**	.646**	.620**	1	
12. Fluid IQ	-.536**	.580**	.350**	.620**	.583**	.254**	.114	-.148	-.168	-.127	.020	1
13. Crystallised IQ	-.016	.258**	.150	.833**	.081	.227**	.129	-.100	-.054	-.048	.136	.305**

***denotes significant at *p*<.05, **denotes significant at *p*<.001. [a]controlling for all confounds (time perception, systolic BP, HRV, resting HR, BMI and inaccuracy of beliefs)**

Figure 1

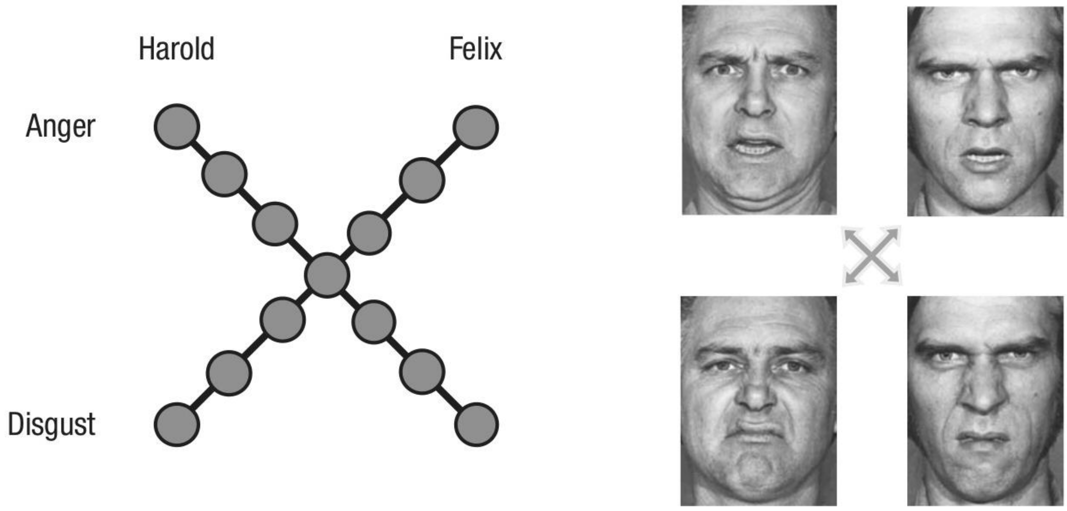

Figure and Table legends

Table 1. Descriptive statistics for all examined factors for both the total and subsamples. Age = age in years. Emotion (Hits-FA) = scores on the emotion recognition task calculated using Hits-FA (see text for details). FSIQ-2 = WASI FSIQ-2 (age normed). Processing speed = Average percentage accuracy across the coding and symbol search subscales of the WAIS. Interoception = interoceptive accuracy. Alexithymia = TAS-20 scores. Depression = BDI scores. Trait anxiety = STAI scores. State anxiety = STAI scores. Fluid IQ = percentage accuracy scores on the matrix subscale of the WASI, measuring fluid intelligence. Crystallised IQ = percentage accuracy scores on the verbal subscale of the WASI, measuring crystallised intelligence.

Table 2. Depicts the correlations between all factors in the total sample. Age = age in years. Emotion (Hits-FA) = Emotion recognition scores calculated as Hits-FA. High scores indicate better performance. Identity (Hits-FA) = Identity recognition scores calculated as Hits-FA. High scores indicate better performance. FSIQ-2 = WASI age-normed FSIQ-2; high scores indicate higher IQ. PS = percentage accuracy on the symbol search and coding subscales of the WAIS; high scores indicate faster processing speed. Interoception = interoceptive accuracy controlling for time perception abilities; high scores indicate better interoceptive accuracy. Alexithymia = TAS-20 scores; high scores indicate higher alexithymic traits. Depression = BDI scores; high scores indicate higher depressive traits. Trait anxiety = STAI scores; high scores indicate higher trait anxiety. State anxiety = STAI scores; high scores indicate higher state anxiety. Fluid IQ = percentage accuracy scores of the matrix subscale of the WASI; high scores indicate higher fluid intelligence. Crystallised IQ = percentage accuracy scores of the verbal subscale of the WASI; high scores indicate higher crystallised intelligence.

Figure 1. Presents an illustration of the cross-morph continua for the emotion-identity recognition task (left) and example end points for each of the continua (right). Faces were morphed along both identity (Harold to Felix) and emotion (Anger to Disgust) axis. Figure adapted from Cook et al., (2013).